

# Biometric Characteristics of the Pelvis in Female-to-Male Transsexuals

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**Abstract** The objective of the study was to evaluate the metric features of pelvises of 24 female-to-male (FtM) transsexuals as compared to control groups of 24 healthy males and 24 healthy females. The participants had their pelvises X-rayed with the same X-ray apparatus and in the same position. Seventeen measurements were taken on the basis of X-ray pictures of FtM transsexuals' pelvises and both comparison groups. Additionally, their body height was compared. The results showed that FtM transsexuals having female body height represent an intermediate size of three pelvic features and male values of five variables. In order to develop a model based on metric variables of the pelvis that would best discriminate the FtM transsexuals, the control females, and the control males, a discriminant analysis was applied. The model included four variables out of 17 metric features: the height of the pubic symphysis, the greatest pelvic breadth, the interischial distance, and the acetabular diameter. The model was found to be the best in discriminating males from females and FtM transsexuals, but considerably less effective in discriminating transsexuals from the two control groups. The results demonstrate that a number of FtM transsexuals' pelvic measurements reveal "masculinization," which confirms current results demonstrating a shift in the somatometric traits of transsexual females towards male traits. A discriminant analysis based only on pelvic metric features shows some differences between the size of the pelvis and chromosomal sex in FtM transsexuals, which might indicate a biological basis for gender identity disorder.

**Keywords** Anthropometrics · Transsexualism · Sexual dimorphism · Gender identity disorder · Pelvis

## Introduction

Sexually dimorphic traits primarily concern somatic, physiological, functional, and psychological human features. Sexual dimorphism is subject to considerable changes during ontogenetic development. Its extent depends on the developmental rate of the trait, the ontogenetic phase, the power of genetic determination as well as the influence of environmental factors. Sexual dimorphism manifests itself morphologically as early as in fetal life, although at that stage it is not very pronounced. Along with development, it advances to achieve a peak in adult life and then decreases along with body ageing (Fink, Neave, & Manning, 2003; Nelson, Vogler, Pederson, & Miles, 1999; Rösing et al., 2007).

Sexual dimorphism with respect to the development of osseous structures used to be ascribed to differences in the male and the female hormonal balance. Hormone activity during adolescence is considered critical for the manifestation of sexual differences. Since the 1960s, it has been accepted (primarily as a result of observation of the development of individuals representing different anomalies of sex chromosomes) that the X and Y chromosomes contain genes controlling osseous maturation. This gene named *SHOX* (short stature homeobox-containing gene) is located on the distal part of the pseudoautosomal region on both sex chromosomes in males and females and is thought to play a role in bone growth and development (Clement-Jones et al., 2000; Ross et al., 2001).

Based on the results of the examination of patients with Klinefelter 47,XXY and Turner 45,X syndromes, it was suspected that the Y chromosome might contain a gene responsible for retarded osseous maturation (Tanner, Prader, Habich, & Ferguson-Smith, 1959) and that the X chromosome might influence the rate

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and the timing of ossification (Garn & Rohmann, 1962). The magnitude of sexually dimorphic differences between adult skeletons makes it possible to identify their sex (with identification accuracy depending on the diagnostic features of bones). As regards the human skeleton, the most pronounced sexual differences are represented by the pelvis and, to a slightly lesser degree, by the cranium (Durić, Rakočević, & Donić, 2005; Kranjoti, Işcan, & Michalodimitrakis, 2008; Krogman & Işcan, 1986; Patil & Mody, 2005; Rösing et al., 2007; Steyn & Işcan, 2008; Uberlaker & Volk, 2002). Krogman and Işcan (1986) claimed that evaluation of the whole skeleton enabled correct sex identification in 100 %, while the identification accuracy fell to 98 % if the examination involved the cranium and pelvis only and to 92 % if it involved the cranium only. According to Phenice (1969), who proposed a sex identification method based on only one pelvic bone (the pubic bone), the accuracy of determination was as high as 95 %.

Transsexualism is a gender identity disorder and it leads to the development of gender identity that is at variance with the morphology of the genitals and the secondary sex characteristics (Gooren, 2006). This condition is characterized by great suffering with a desire to be socially accepted in the role which is in accordance with the preferred sex (Antoszewski, Kasielska, Jędrzejczak, & Kruk-Jeromin, 2007). Transsexuals feel as if they were “incarcerated in a foreign body” and thus they may wish to change their sexual features through hormonal therapy and surgical treatment.

Despite a large number of studies, the etiology of transsexualism remains unclear and gives rise to numerous controversies. Current hypotheses suggest psychosocial (Fajkowska-Stanik, 1999; Zucker & Green, 1993) or biological causes of gender identity disorder, demonstrating a potential role of neurophysiological (Bao & Swaab, 2011; Dorner, Poppe, Stahl, Kölzsch, & Uebelhack, 1991; Garcia-Falgueras & Swaab, 2008; Swaab & Hofman, 1995), endocrine (Kula & Słowikowska-Hilczer, 2000, 2003), and genetic factors (Green, 2000; Green & Keverne, 2000; Segal, 2007).

Clinically, two main types of transsexualism are distinguished: female-to-male (FtM) and male-to-female (MtF). According to the widely accepted definition, FtM transsexuals have a female phenotype, but identify themselves with the male gender, while MtF transsexuals have a male body, but identify themselves as females (Imieliński, Dulko, & Filar, 1997). The above characteristic of transsexualism is based on the assumption that the morphological structure of the patient's body is consistent with his or her sex as determined by his or her sexual organs. A large number of researchers, however, indicate intermediate values of various anthropometric traits of transsexuals (Antoszewski, Kruk-Jeromin, & Malinowski, 1998; Bosinski et al., 1997; Malinowski, Antoszewski, & Kruk-Jeromin, 1996), including odontometric features which are strongly determined by genes (Antoszewski, Żądzińska, & Foczański, 2009). This intermediate body build places transsexuals between the metric characteristics of males and females who reveal correct sex identification.

The objective of our study was to examine whether anthropometric characteristics of the pelvis (being the most dimorphic

structure in the human skeleton) are male-typical in FtM transsexuals.

## Method

### Participants

The Department of Plastic, Reconstructive, and Aesthetic Surgery, Medical University of Lodz, provides care for 302 FtM transsexuals. The study involved 24 patients who, due to diagnostic and therapeutic recommendations (pain in hip joints), had their pelvises X-rayed. The average age of the individuals studied was 26.44 years ( $SD = 3.89$ ; range 21–34). All the patients had undergone psychiatric, psychological, sexological, endocrine, and gynecological examinations leading to a diagnosis of FtM transsexualism. The examined transsexuals had been administered hormone therapy at the age between 20 and 25 years ( $M$  age, 21.58 years;  $SD = 1.64$ ). At the time of performing the X-rays, they had been taking hormones for a period ranging from 1–10 years ( $M$  period, 4.88 years;  $SD = 2.58$ ). The treatment was commenced after the completion of the legal sex change procedures (birth certificate, identity card). The examined patients were before, during or after surgical sex reassignment. Three patients had completed surgical procedures (breast reduction, total hysterectomy, penis and scrotum reconstruction), the rest of the patients, due to the exclusion of such operations from the list of procedures refunded by the NHS, had not decided to start (1 person) or to accomplish (20 patients) the comprehensive surgical schedule.

For comparison purposes, we made use of pelvic X-rays of 48 persons (24 females and 24 males) who suffered from pelvic pain but did not reveal any gender identity disorder or pelvic injuries, at an age corresponding to the age of the transsexuals involved in the study (range of the females' age: 25–37 years; range of the males' age: 26–39 years;  $M = 31.5$  years;  $SD = 4.21$ ).

### Procedure

The indication for a pelvic X-ray in the whole group (the patients and the control males and females) was pain in the hip joints. There were no pathological changes diagnosed in the structure of the pelvis in anyone within the examined group. Those persons had not experienced any trauma to their pelvic bones and their medical history did not reveal any important issues (the patients did not train any professional sports nor had a job requiring hard physical work). None of the transsexual females and none of the healthy females in the control group had ever delivered or been pregnant for longer than 3 months.

All the X-ray pictures were taken in the Institute of Radiology, Medical University of Lodz, with the same X-ray apparatus in the position with the distal end of the coccyx superimposed on the upper edge of the pubic symphysis.

## Measures

Seventeen measurements (15 linear measurements, including breadth, length, and two angles) were taken with the use of the pelvic X-ray pictures of the FtM transsexuals and the comparison groups (Table 1; Fig. 1a, b).

Additionally, body height (B–v) was measured in order to examine whether the possible tendency of pelvic dimensions towards values characteristic of males might be accounted for by atypical body size of transsexual females. All the pelvic measurements were carried out by one person who did not know whose X-ray was being measured (female, male, or FtM transsexuals). In order to evaluate the accuracy of the performed measurements, the same researcher repeated every measurement on all the pelvic X-rays. The technical error of measurement (TEM) and the coefficient of reliability ( $R$ ) were calculated according to the formula (Ulijaszek & Lourie, 1994):

$$\text{TEM} = \sqrt{\frac{\sum D^2}{2N}}$$

where  $D$  is the difference between repeated measurements and  $N$  is the number of individuals measured.

$$R = 1 - \left[ \frac{\text{TEM}^2}{\text{SD}^2} \right]$$

SD is the standard deviation for a particular measurement (calculated on the basis of all results from the first and second sets of measurements).

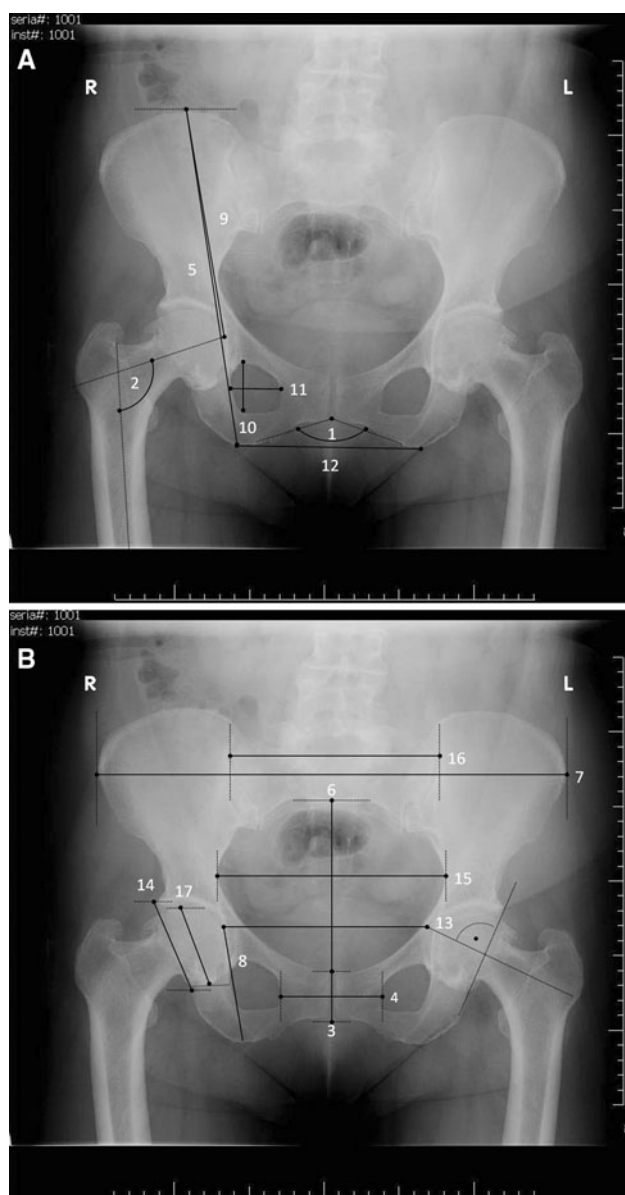
## Statistical Analysis

Prior to a statistical analysis of the metric data, the normality of distribution of the tested variables was examined (using the Kolmogorov–Smirnov test), and then the homogeneity of variances of the characteristics was checked (using the Levene test). With both assumptions met, the single-factor analysis of variance (ANOVA) was applied to identify individual features discriminating the groups (FtM transsexuals, control females, control males). When the results were significant ( $p < .05$ ), Tukey's method, also known as the HSD test, was applied to detect significant differences between pairs of groups. If none of these assumptions was met, the ANOVA test of the Kruskal–Wallis ranks and then multiple comparisons of mean ranks were applied.

In order to develop a model based on variables which would be most effective in discriminating healthy females and males in respect to the pelvic features, a discriminant (backward stepwise) analysis was used. The same analysis was next applied for making a separate model for all three groups: FtM transsexuals, control females, and control males. This method consists in including all the metric variables studied and a successive elimination of those with values smaller than a predefined discrimination measure. As a result of a successful discriminant function analysis, one would only keep the “important” variables in the model, that is, those variables that contribute the most to the discrimination between the groups. In the analysis the definitions of models were automatically generated by statistical package including tolerance, F to enter, F to remove, and the number of steps. Body height was not included because our aim

**Table 1** Performed pelvic measurements and their description

No	Measurement	Description of measurement
1	Subpubic angle	Formed by the inferior rami of the pubis
2	Femoral neck-shaft angle	Formed by the long axes of the neck and the shaft of the right femur
3	Height of pubic symphysis	The distance between the upper and the lower edge of the symphysis
4	Breadth of pubic symphysis	The smallest distance between the most medial points on the inner surface of the obturator foramen
5	Breadth of femur head	The distance between the uppermost point of the iliac crest and the lowest point of the ischial tuberosity
6	Anatomical conjugate (sagittal diameter of pelvic inlet)	The distance between the sacral promontory and the posterior border of the upper surface of the pubic symphysis
7	Greatest breadth of pelvis	The distance between the farthest apart points of the iliac crests
8	Height of ischium	The distance between the midpoint of the acetabulum and the lowest point of the ischial tuberosity
9	Height of ilium	The distance between the midpoint of acetabulum and the highest point of the iliac crest
10	Length of right obturator foramen	The distance between the uppermost point of the superior surface of the right foramen and the lowest point on its inferior surface
11	Breadth of right obturator foramen	The distance between the horizontally farthest apart points of the right obturator foramen
12	Interischial distance	The distance between the ischial spines
13	Interacetabular distance	The distance between the midpoints of the acetabula
14	Acetabular diameter	The greatest breadth of the acetabulum
15	Breadth of pelvic inlet	The distance between the laterally farthest apart points of the pelvic inlet
16	Upper breadth of sacrum	The distance between the laterally farthest apart points of the auricular surfaces
17	Height of pelvis	The greatest distance between opposite points at the circumference of the right femur head



**Fig. 1** Pelvic graph with the performed measurements marked

was to show how pelvic measurements differ between FtM transsexuals, males, and females.

## Results

Table 2 provides statistical characteristics of the traits analyzed for males, females, and FtM transsexuals. As the distributions of these variables in all of the groups did not differ significantly from normal distribution, they were described with means and SDs. The values of *R* ranged from 0.92 to 0.99; this means that more than 92 % of the variability in the measurements was caused by factors other than the calculated measurement error.

Table 3 shows the results of one-way tests (the ANOVA or the Kruskal–Wallis test) and post hoc tests (HSD Tukey's or multiple

comparisons of mean ranks test). The effect size, representing the proportion of total feature variance, which can be ascribed to the examined independent variable (the group), was the smallest for the femoral neck-shaft angle (partial  $\eta^2$  14.27 % and  $\omega^2$  11.64 %) and the biggest for the subpubic angle and the interischial distance (partial  $\eta^2$  80.29 and 80.58 %;  $\omega^2$  79.49 and 79.79 %, respectively) (Table 3).

### Male versus Female Comparison

In the group of 18 anthropometric features, 17 of them were significantly different between the control males and the control females. Eight features had higher values in males than in females: the body height, the femoral neck-shaft angle, the height of the pubic symphysis, the height of the ischium, the height of the pelvis, the height of the ilium, the acetabular diameter, and the breadth of the femur head. Nine were bigger in females than in males: the anatomical conjugate, the greatest breadth of the pelvis, the interacetabular distance, the breadth of the pelvic inlet, the upper breadth of the sacrum, the subpubic angle, the breadth of the pubic symphysis, the breadth of the right obturator foramen, and the interischial distance. Only one feature did not distinguish both groups (the length of the right obturator foramen) (Tables 3, 4).

### Male versus FtM Transsexuals Comparison

In the group of the analyzed features, male values were found in six variables: the femoral neck-shaft angle, the anatomical conjugate, the greatest breadth of the pelvis, the interacetabular distance, the breadth of the pelvic inlet, and the upper breadth of the sacrum.

Those features were different from values typical of females, but there were no significant differences in comparison with the control males (Tables 3, 4).

### Female versus FtM Transsexuals Comparison

Our data showed that FtM transsexuals had female body height. Additionally, female values were found in the height of the pelvis, the height of the ilium, the breadth of the right obturator foramen, the interischial distance, and the acetabular diameter. Those features were different from values typical of males, but there were no significant differences in comparison with the control females (Tables 3, 4).

### Intermediate Features

The results obtained demonstrated that FtM transsexuals represent an intermediate magnitude of four pelvic features: the subpubic angle, the height and the breadth of the pubic symphysis, and the height of the ischium. Those features were sexually dimorphic between healthy controls and at the same time placed FtM transsexuals between values typical of males and females (Tables 3, 4).

**Table 2** Anthropometric features of FtM transsexuals, control males (M), and control females (F)

Feature	M <i>n</i> = 24		F <i>n</i> = 24		FtM <i>n</i> = 24		TEM <i>n</i> = 72	<i>R</i> <i>n</i> = 72
	M	SD	M	SD	M	SD		
B–v (cm)	177.41	6.83	165.61	5.22	165.40	6.61	–	–
Femoral neck-shaft angle (°)	131.25	4.97	127.63	4.67	131.83	4.32	1.05	0.96
Anatomical conjugate (mm)	134.21	6.53	143.25	9.42	136.46	9.31	1.71	0.97
Greatest breadth of pelvis (mm)	324.58	9.18	352.88	18.76	325.58	8.26	2.14	0.99
Interacetabular distance (mm)	147.00	6.89	162.00	10.24	151.96	8.53	1.74	0.97
Breadth of pelvic inlet (mm)	151.83	4.90	165.92	9.28	155.00	6.39	0.80	0.99
Upper breadth of sacrum (mm)	133.58	3.53	141.21	8.90	136.88	4.95	0.85	0.99
Subpubic angle (°)	91.67	7.48	130.75	6.24	124.13	11.38	1.11	0.99
Height of pubic symphysis (mm)	36.25	3.65	27.38	3.69	31.04	2.49	0.55	0.99
Breadth of pubic symphysis (mm)	59.04	5.03	71.88	7.42	66.54	6.38	0.87	0.99
Height of ischium (mm)	96.21	4.43	80.17	16.12	89.13	4.24	1.76	0.97
Height of pelvis (mm)	260.67	7.18	246.63	7.60	245.79	7.44	2.18	0.96
Height of ilium (mm)	164.21	5.01	158.17	5.07	159.67	5.21	1.69	0.92
Breadth of right obturator foramen (mm)	25.21	3.34	29.17	2.82	30.13	2.36	0.75	0.96
Interischial distance (mm)	91.33	7.96	121.50	7.71	122.38	5.86	1.51	0.99
Acetabular diameter (mm)	65.00	3.01	59.00	3.43	58.29	2.73	0.56	0.98
Length of right obturator foramen (mm)	32.00	4.59	31.71	2.80	36.67	3.73	0.92	0.96
Breadth of femur head (mm)	57.38	2.90	54.04	3.17	51.75	2.69	0.52	0.98

*B* (basis) the plane on which the patient stands, *v* (vertex) the uppermost point of the head measured in Frankfurt plane, *TEM* technical error of measurement, *R* coefficient of reliability

**Table 3** Results of one-way comparisons of body height and pelvic anthropometric features of FtM transsexuals, control males (M), and control females (F)

Feature	ANOVA test/Kruskal–Wallis test		Effect size		Post hoc HSD Tukey's test/multiple comparisons of mean ranks test		
	<i>F</i> / <i>H</i>	<i>p</i>	$\eta^2$ (%)	$\omega^2$ (%)	F vs. M	FtM vs. F	FtM vs. M
B–v	28.91	<.001	45.59	43.67	<.001	ns	<.001
Femoral neck-shaft angle	5.74	.005	14.27	11.64	.024	.007	ns
Anatomical conjugate	7.32	.001	17.50	14.93	.001	.020	ns
Greatest breadth of pelvis	36.77	<.001	51.59	49.84	<.001	.000	ns
Interacetabular distance	18.68	<.001	35.13	32.94	<.001	.001	ns
Breadth of pelvic inlet	26.04	<.001	43.02	41.03	<.001	.000	ns
Upper breadth of sacrum	9.06	<.001	20.80	18.30	<.001	.048	ns
Subpubic angle	140.50	<.001	80.29	79.49	<.001	.026	<.001
Height of pubic symphysis	43.16	<.001	55.58	53.94	<.001	.001	<.001
Breadth of pubic symphysis	24.73	<.001	41.75	39.73	<.001	.013	<.001
Height of ischium	15.65	<.001	31.21	28.93	<.001	.008	.042
Height of pelvis	30.53	<.001	46.95	45.06	<.001	ns	<.001
Height of ilium	9.14	<.001	20.95	18.45	<.001	ns	.008
Breadth of right obturator foramen	19.81	<.001	36.47	34.32	<.001	ns	<.001
Interischial distance	143.11	<.001	80.58	79.79	<.001	ns	<.001
Acetabular diameter	34.66	<.001	50.12	48.32	<.001	ns	<.001
Length of right obturator foramen	13.02	<.001	27.41	25.04	.961	.001	<.001
Breadth of femur head	22.41	<.001	39.38	37.30	.001	.023	<.001

$\eta^2$  (partial eta squared) effect size in the sample (for the independent variable “the group” including three variants: females, males and FtM transsexuals),  $\omega^2$  (omega squared) effect size for the population

## Other Features

The other two dimensions were different from the values characterizing the comparison groups: the length of the right obturator foramen did not discriminate healthy females and males, while it was significantly larger in the transsexuals than in the control males and the control females. On the other hand, the breadth of the femur head in the transsexuals was found to be smaller relative to that in both the male and the female comparison groups (Tables 3, 4). In healthy adults, this feature is generally smaller in females than in males. According to our results, FtM transsexuals had an even smaller value of this variable than the control females, which is why this feature was called “hyperfeminized” (Table 4).

## Discriminant Analysis

The first discriminant model was developed only for two groups: the control males and the control females. The most important distinguishing features were: the subpubic angle, the femoral neck-shaft angle, the height of the pelvis, the greatest breadth of the pelvis, the breadth of the right obturator foramen, the acetabular diameter, the breadth of the pelvic inlet, and the upper breadth of the sacrum (Table 5). For the above-mentioned features, classification functions were calculated (Table 6).

## Classification Functions for Males

$-1119.58 + 0.69$  subpubic angle  $+ 5.22$  femoral neck-shaft angle  $+ 9.41$  height of pelvis  $- 1.37$  greatest breadth of pelvis  $+ 3.58$  breadth of right obturator foramen  $- 7.05$  acetabular diameter  $- 2.75$  breadth of pelvic inlet  $+ 1.99$  upper breadth of sacrum

**Table 5** Variables of the discriminant model based on metric features of the pelvis of control females and control males (2 groups)

Feature	Wilks' lambda	Partial Wilks' lambda	F elimination	p
Subpubic angle	0.059	0.420	53.83	<.001
Femoral neck-shaft angle	0.030	0.833	7.83	<.001
Height of pelvis	0.029	0.855	6.62	.014
Greatest breadth of pelvis	0.049	0.511	37.28	<.001
Breadth of right obturator foramen	0.028	0.890	4.80	.034
Acetabular diameter	0.028	0.891	4.75	.035
Breadth of pelvic inlet	0.032	0.781	10.93	.002
Upper breadth of sacrum	0.041	0.605	25.47	<.001

**Table 4** Summary of the results of one-way comparisons of body height and pelvic anthropometric features of FtM transsexuals, control males (M), and control females (F)

Feature	Feature dimorphism (F vs. M)	Feature value in FtM			
		Male	Intermediate	Female	Other
B–v	Present			+	
Femoral neck-shaft angle	Present	+			
Anatomical conjugate	Present	+			
Greatest breadth of pelvis	Present	+			
Interacetabular distance	Present	+			
Breadth of pelvic inlet	Present	+			
Upper breadth of sacrum	Present	+			
Subpubic angle	Present		+		
Height of pubic symphysis	Present		+		
Breadth of pubic symphysis	Present		+		
Height of ischium	Present		+		
Height of pelvis	Present			+	
Height of ilium	Present			+	
Breadth of right obturator foramen	Present			+	
Interischial distance	Present			+	
Acetabular diameter	Present			+	
Length of right obturator foramen	Absent				Longer than in male and female
Breadth of femur head	Present				Hyperfeminized

“+” determines the “character” of the feature in FtM transsexuals (on the basis of the post hoc test presented in Table 3)

**Table 6** Coefficients of the discriminant functions for the model based on metric features of the pelvis of control males and control females (2 groups)

Feature	Male $p = .50$	Female $p = .50$
Subpubic angle	0.69	2.47
Femoral neck-shaft angle	5.22	4.05
Height of pelvis	9.41	8.07
Greatest breadth of pelvis	−1.37	0.36
Breadth of right obturator foramen	3.58	1.83
Acetabular diameter	−7.05	−9.47
Breadth of pelvic inlet	−2.75	−1.03
Upper breadth of sacrum	1.99	−1.08
Constant	−1119.58	−1064.72

*Classification Functions for Females*

−1064.72 + 2.47 subpubic angle + 4.05 femoral neck-shaft angle + 8.07 height of pelvis + 0.36 greatest breadth of pelvis + 1.83 breadth of right obturator foramen − 9.47 acetabular diameter − 1.03 breadth of pelvic inlet − 1.08 upper breadth of sacrum.

In accordance with the expectations, the classification of females and males based on the above-mentioned measurements was very accurate (100 %). Furthermore, the classification of FtM transsexuals turned out to be quite interesting. For the above functions, the transsexual group was a set of “new” cases. According to biological sex, the transsexuals were females, but nine (37.5 %) in the examined group were classified as male (Table 7).

The second discriminant model developed for distinguishing the three groups (females, males, transsexuals) included four variables out of the 17 analyzed metric features of the pelvis: the height of the pubic symphysis, the greatest breadth of the pelvis, the interischial distance, and the acetabular diameter (Table 4). The remaining 13 dimensions were eliminated from the model, as they were non-significant with respect to general discrimination. The model proved to be highly significant ( $p < .0001$ ). General discrimination was largely based on the interischial distance. The value of partial Wilks' lambda was the smallest for this variable. The height of the pubic symphysis represented the lowest, but still significant, discriminant power in this model (Table 8).

Based on the standardized indices of the discriminating functions, it was found that the first discriminant function was primarily influenced by the acetabular diameter and the interischial distance, while the other one was primarily determined by the greatest breadth of the pelvis. The tests demonstrated that both discriminant functions were significant at  $p < .0001$  and the first one was responsible for 79 % of the variance explained, while the other one for the remaining 21 % (Table 9).

The next step in the analysis was to determine the nature of discrimination for each function. The mean values of canonical variables made it possible to find that the first discriminant function

**Table 7** Matrix of the classification based on metric features of the pelvis of control males and control females

Group	Classified correctly (%)	Predicted classification	
		Male	Female
Males	100.00	24	0
Females	100.00	0	24
Transsexuals	62.50	9	15

**Table 8** Variables of the discriminant models based on metric features of the pelvis of FtM transsexuals, control males, and control females

	Wilks' lambda	Partial Wilks' lambda	F elimination	p
Height of pubic symphysis	0.042	0.671	16.20	<.001
Greatest breadth of pelvis	0.072	0.385	52.67	<.001
Interischial distance	0.106	0.263	92.60	<.001
Acetabular diameter	0.045	0.616	20.61	<.001

discriminated primarily males from females and FtM transsexuals, while the second function discriminated transsexuals from healthy females and males (Table 10). It should, however, be noted that, in accordance with previous results, the magnitude of determination of the former function was considerably larger than that of the latter, which was proved by the dispersion of canonical values (Fig. 2). This means that the model was better suited to discriminating males from females and transsexuals, while it was considerably less effective in discriminating transsexuals from the other two groups (males and females).

Subsequently, the results of the discriminant analysis were used for the classification of particular cases. For this purpose, classification functions were developed for each group, and individual cases were assigned to the group for which they represented the highest classification value. As the analysis involved samples of identical size, and degrees of probability proportional to their size were selected to develop classification functions, the a priori probability for each group amounted to one-third (Table 11).

*Classification Functions for Males*

−347.152 − 1.415 height of pubic symphysis + 1.695 greatest breadth of pelvis − 0.526 interischial distance + 3.713 acetabular diameter

*Classification Functions for Females*

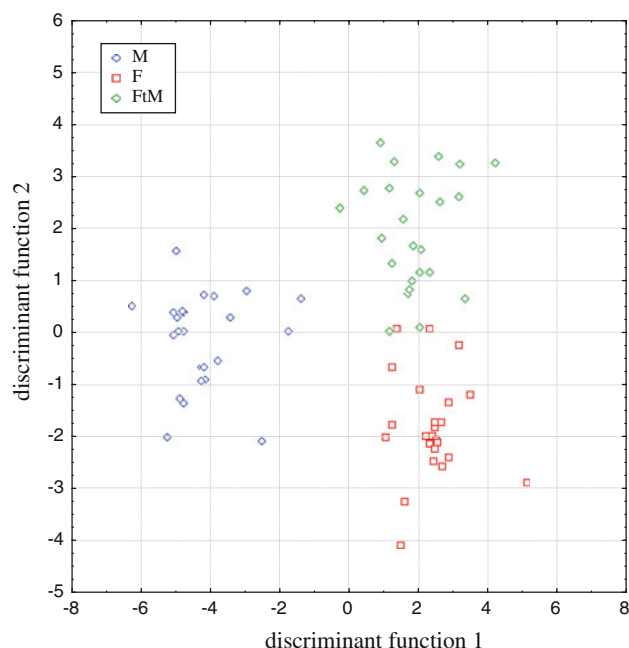
−392.508 − 2.003 height of pubic symphysis + 2.034 greatest breadth of pelvis + 0.122 interischial distance + 1.778 acetabular diameter

**Table 9** Raw and standardized coefficients of the discriminant functions for the model based on metric features of the pelvis of FtM transsexuals, control males, and control females

	Raw coefficient		Standardized coefficient	
	First discriminant function	Second discriminant function	First discriminant function	Second discriminant function
Height of pubic symphysis	−0.02493	0.25547	−0.082919	0.84956
Greatest breadth of pelvis	0.02658	−0.09935	0.344747	−1.28846
Interischial distance	0.12600	0.10876	0.912032	0.78721
Acetabular diameter	−0.30001	−0.02292	−0.920078	−0.07029
Variance explained	0.79067	1.00000		

**Table 10** Mean canonical values for the model based on metric features of the pelvis of FtM transsexuals, control males, and control females

Group	First discriminant function	Second discriminant function
Males	−4.21830	−0.14679
Females	2.35621	−1.80631
Transsexuals	1.86209	1.95310

**Fig. 2** Dispersion diagram of the canonical values (values of the discriminant functions)

#### Classification Functions for FtM Transsexuals

−335.674 − 1.030 height of pubic symphysis + 1.648 greatest breadth of pelvis + 0.469 interischial distance + 1.840 acetabular diameter

**Table 11** Coefficients of the classification functions for the model based on metric features of the pelvis of FtM transsexuals, control males, and control females

	Males <i>p</i> = .33	Females <i>p</i> = .33	FtM transsexuals <i>p</i> = .33
Height of pubic symphysis	−1.415	−2.003	−1.030
Greatest breadth of pelvis	1.695	2.034	1.648
Interischial distance	−0.526	0.122	0.469
Acetabular diameter	3.713	1.778	1.840
Constant	−347.152	−392.508	−335.674

*p* the a priori probability for each group amounted to one-third

**Table 12** Matrix of the classification based on metric features of the pelvis of FtM transsexuals, control males, and control females

Group	Classified correctly (%)	Predicted classification		
		Males	Females	FtM transsexuals
Males	100.00	24	0	0
Females	95.83	0	23	1
Transsexuals	100.00	0	0	24

The classification results demonstrate that the identification of males and transsexuals was the most accurate, and the identification of females was slightly less precise—only one woman was classified as FtM transsexual (Table 12). However, it should be noted that the case classification results which provided the basis for developing the discriminant functions could not be used for the predictive evaluation of their discriminant power, but only for the identification of the strengths and the weaknesses of the classification functions. Due to the lack of standardized pelvic X-ray pictures of a larger number of transsexuals, males, and females, it was impossible to test the developed discriminant functions on “new” cases.

#### Discussion

Anthropometric analyses of transsexuals are based on the features which are sexually dimorphic in the population of individuals

without gender identity disorder. Morphological differences between healthy females and healthy males determine the so-called sexual dimorphism pattern, which makes it possible to interpret the somatic structure of transsexuals and to determine the direction of deviations that may occur in the morphology of the structures analyzed. Initially, sexually dimorphic features were primarily interpreted as a consequence of sex hormones activated during sexual maturation. Nowadays, at least a number of them are thought to be influenced by the hormones responsible for masculinization or feminization which are active as early as in the prenatal period (Fink et al., 2003). Endocrinologically, there are two stages prior to adolescence when the secretion of sex hormones approximates the secretion of those hormones in adults: the gestational weeks 12–18 and the first half year of life (Perera, McGarrigle, Lawrence, & Lucas, 1987; Reinisch, Ziemba-Davis, & Sanders, 1991). The next stage occurs during puberty. All of these periods are associated with endocrine activity. In male fetuses, sex differentiation is a direct result of significant prenatal testosterone secretion (controlled by the SRY genes). These hormonal differences could therefore produce differences in male and female skeletons exposed to fluctuating hormone levels in utero (Byrger et al., 1991; Loth & Henneberg, 2001) by influencing the secretion of the bone morphogenetic proteins (BMPs), especially the growth and differentiation factor 5 and BMP-7—the cell-signaling molecules with key roles in the growth and development of the child's hip (Lee & Eberson, 2006). Consequently, according to Wells (2007), gender development disorders are related to morphological aberrations triggered by hormones.

The studies carried out to date demonstrate that a number of odontometric, cephalometric, and somatometric features of FtM transsexuals show values intermediate between those typical of males and those typical of females. These include the mesiodistal dimension of the medial incisor of the maxilla and of the first molar of the mandible, the BL dimension of the canine, of the first molar of the maxilla, and of both incisors of the mandible (Antoszewski et al., 2009), the forehead breadth, the mandible breadth, the full facial height (Malinowski et al., 1996), the trunk length, the symphyseal height, the breadth of the knee, and the chest circumference (Antoszewski et al., 1998). A number of features reveal typically male mean values, including the BL dimension of the second molar of the maxilla and the MD dimension of the second molar of the mandible (Antoszewski et al., 2009), the upper face height (Malinowski et al., 1996), the waist girth, the upper arm girth (Bosinski et al., 1997), the biacromial breadth, the breadth and the sagittal diameter of the chest, and the force of hand (Antoszewski et al., 1998).

A number of proportions of FtM transsexuals' bodies also demonstrate a tendency towards values typical of healthy males. These include the waist-to-hip ratio (Bosinski et al., 1997), the lower limb indices, Quetelet's index,<sup>1</sup> Marty's index,<sup>2</sup> and Pignet–Verwaeck's

index<sup>3</sup> (Antoszewski et al., 1998), and typically male proportions, including the hip–tail-index, the radioulnar breadth/forearm length, the radioulnar breadth/body height, the waist breadth/body height, the waist girth/body height, and the forearm girth/body height (Bosinski et al., 1997). The studies by Antoszewski et al. (1998), Bosinski et al. (1997), and Malinowski et al. (1996) were conducted using direct anthropometric methods and included features which were not analyzed in the present study. Unfortunately, the use of a different methodology made it impossible to compare the results obtained, but all the above-mentioned results demonstrate the same direction of modifications in FtM transsexuals' body structure.

We tried to identify differences in the FtM transsexuals' skeletal structure as compared to that of healthy females and males. We analyzed measurements of the pelvis, since this is the part of the skeleton in which sexual features manifest themselves most distinctly. It was found that out of 17 sexually dimorphic features, nearly half showed a male tendency in the body structure (the subpubic angle, the height and the breadth of the pubic symphysis, the height of the ischium), or even values typical of males (the femoral neck-shaft angle, the anatomical conjugate, the greatest breadth of the pelvis, the interacetabular distance, the breadth of the pelvic inlet, and the upper breadth of the sacrum).

The results of previous studies concerning intersex differences in the femoral neck-shaft angle revealed a non-homogeneous pattern of sexual dimorphism in different populations (Anderson & Trinkaus, 1998). It is thought that this feature showed small and inconsistent sexual differences (Anderson & Trinkaus, 1998). This can explain why this feature was not found among the most important discriminant variables distinguishing the three examined groups. However, in our study, the discriminant analysis for two groups (the control males and the control females) classified this feature as one of the most sexually dimorphic ones. It is interesting to observe that the features which have preserved a typically female character in FtM transsexuals have a less significant meaning with respect to the reproductive function, especially the pelvic height, the height of the ilium, the breadth of the right obturator foramen, the height of the ischium, and the acetabular diameter.

The fact that in anthropometric studies of transsexuals treated with hormone therapy a number of morphological aberrations were interpreted as changes independent of the applied treatment may raise doubts. The material providing the basis for the present study demonstrated that transsexuals began hormonal treatment at the age of 20 at the earliest, while studies on biomorphosis prove that at that age pelvic height and body height have attained their ultimate values (Scheuer, Black, & Christie, 2000). According to Gooren (1999), the masculinization and feminization processes are completed under the influence of natural hormones by the time adult transsexuals commence their hormonal treatment. Gooren stated that in MtF transsexuals prior influence of androgens on the skeleton

<sup>1</sup> Quetelet's index: body weight (g)/body height (cm).

<sup>2</sup> Marty's index: 100(chest circumference (cm)/body height (cm)).

<sup>3</sup> Pignet–Verwaeck's index: 100((body weight (kg) + chest circumference (cm))/body height (cm)).

(resulting in larger average body height, the size and the shape of the hands, the feet and the mandible, and the masculine pelvic structure) could not be reversed. Similarly, the body height of FtM transsexuals and the female structure of their pelvises remain unchanged by the action of androgens.

Given the above, it should be noted that the shift in the magnitude of pelvic features towards male values in individuals with female body height observed in the present study may be interpreted as independent of hormone therapy used by transsexual females. Pursuant to interviews with the transsexual patients, the shift definitely does not result from training professional sports. Thus, the causes of morphological masculinization and other anatomical features of transsexuals seem to have a deeper root and their origin may be related to the very beginning of ontogenesis.

Discriminant analysis is a popular method used in medicine (including forensic medicine) and in archeology. Anthropometric measurements of the skeleton or parts of it allow the development of an analytical model which may determine the sex of bones with a large probability (Durić et al., 2005; Luo, 1995; Rissech, García, & Malgosa, 2003; Steyn & İşcan, 2008). The discriminant analysis used in the present study on the basis of pelvic measurements taken in three groups makes it possible to develop a model assigning measurement results to one of these groups. The high percentage of correctly identified cases proves that the methodology applied was adequate.

The present study was not free from certain limitations, including the small number of the studied patients and the fact that the model was not tested by classifying “new” cases. One should remember that X-rays are not free from risk and performing X-ray examinations without particular diagnostic indications may cause some ethical concerns. For a correct evaluation of the predictive power of the classification functions used, they should be verified on a sample of males and females with a correct gender identity. Collecting further data will allow such an evaluation, and the results presented by us may encourage other researchers to conduct similar analyses involving populations of transsexuals of different ethnic origins.

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